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GB 1521727
GB 1511786
GB 1422470
GB 1013266
GB 0790057
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(54) Monitoring loads in rotating bearings

(57) A method of monitoring the total load, especially axial thrust, on a rotating bearing, e.g. a ball bearing 11, 12, 13, in which piezoelectric, resistive or fibre optic, strain gauges are placed adjacent the outer race 13 of the bearing at locations 21—26 to detect variations in the stress or strain characteristic occurring at the ball (one of which is 12) pass frequency. The amplitude of these variations is translated into a measure of the total load. The strain gauges are included in a bridge circuit.

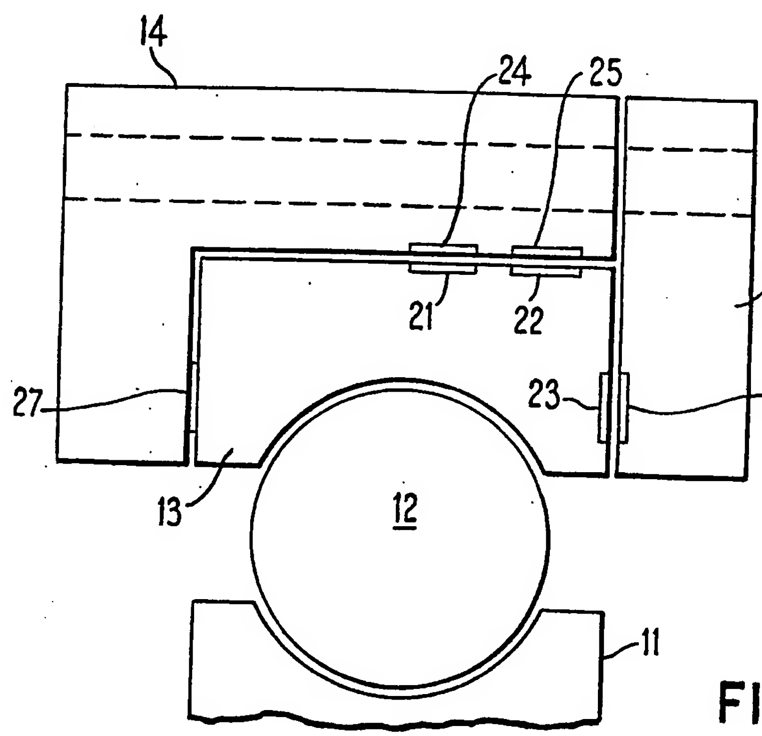


FIG.2

GB 2 113 845 A

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

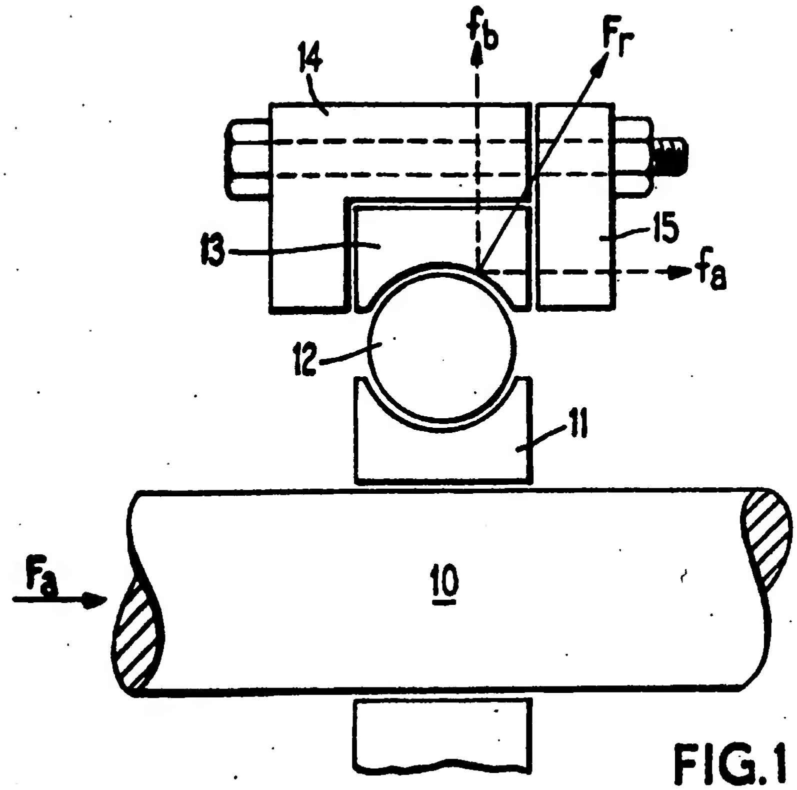


FIG.1

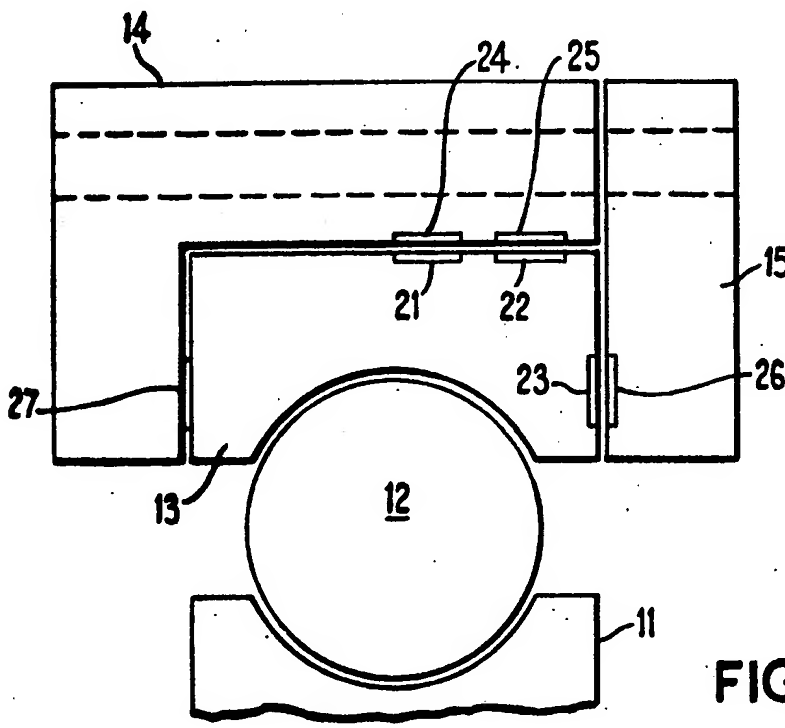


FIG.2

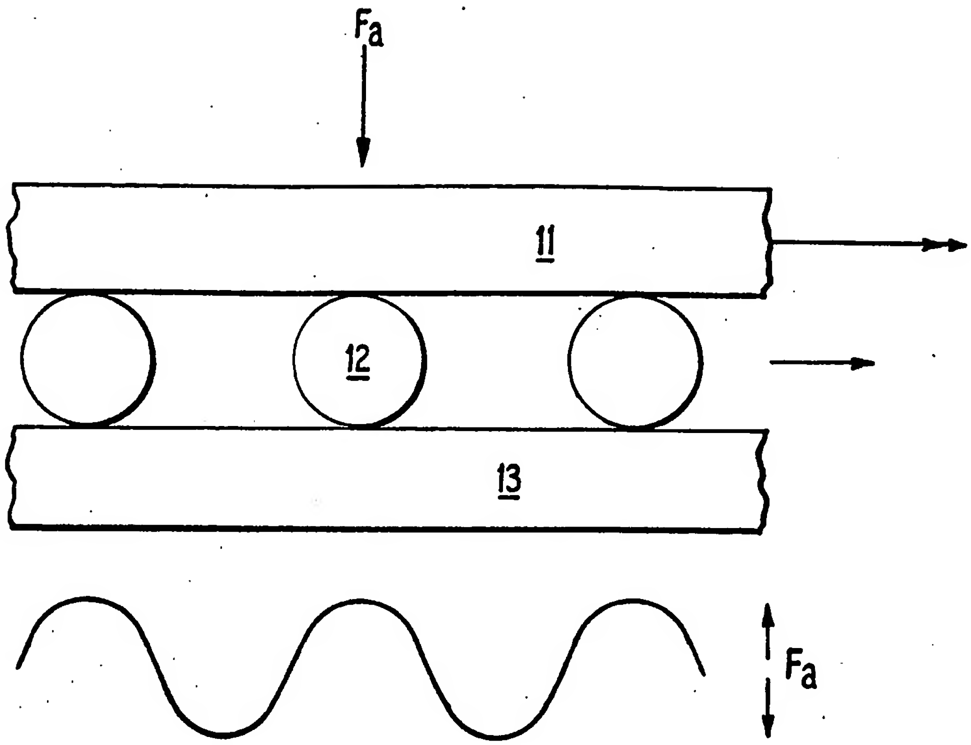

Fa
11
12
13
Fa

FIG.3

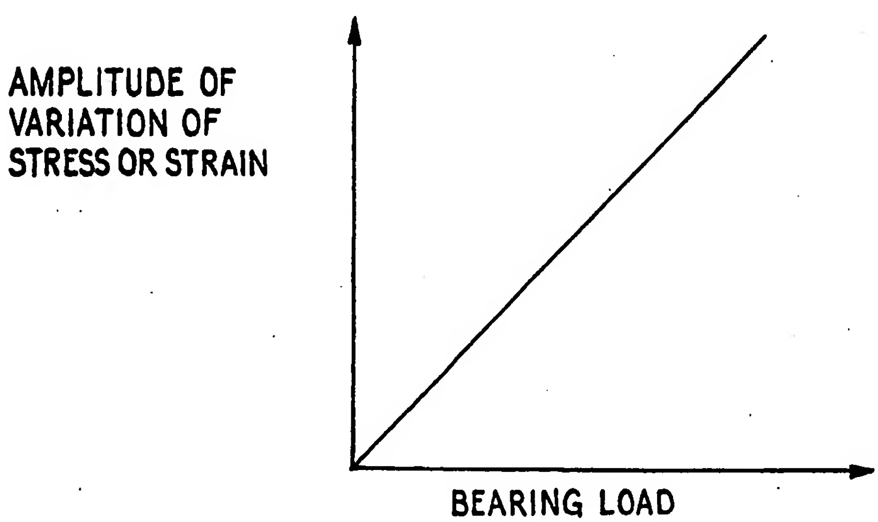
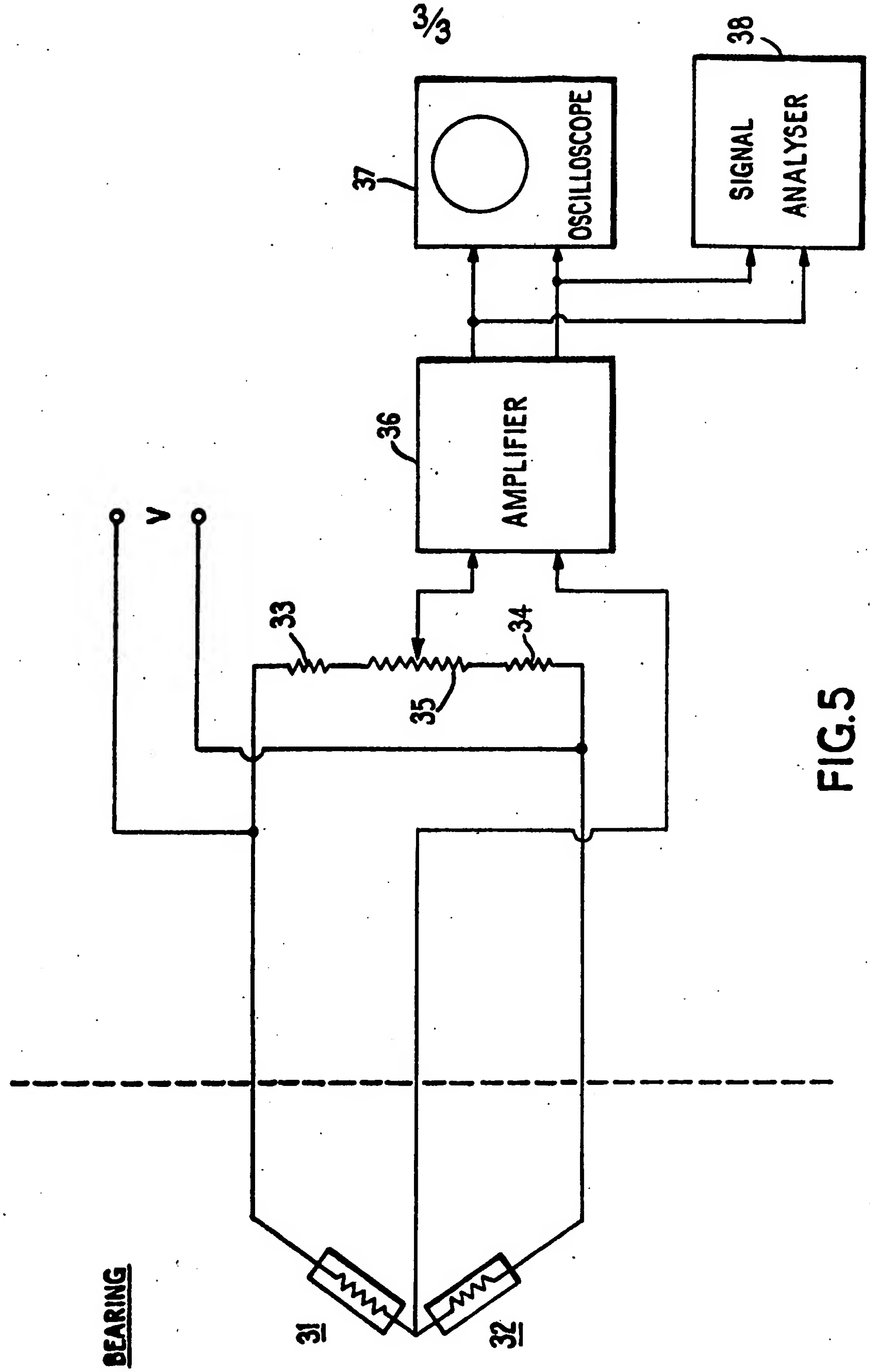

AMPLITUDE OF
VARIATION OF
STRESS OR STRAIN
BEARING LOAD

FIG.4



38
SIGNAL ANALYSER
37
OSCILLOSCOPE
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AMPLIFIER
V
33
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BEARING
31
32

FIG.5

SPECIFICATION

Monitoring of loads in rotating bearings

This invention relates to a method of monitoring the total load, especially axial thrust load, on a rotating ball or roller bearing. The method is suitable for bearing in machines, e.g. pumps and engines, and also for larger industrial bearings, e.g. the azimuth bearing at the base of a crane.

It is already known to introduce sensors into bearings to monitor the wear and performance characteristics. "Rotating Machinery Bearing Analysis", Mechanical Engineering, July 1980, pp 28—33, discloses the use of a fibre optic probe technique for this purpose. A fibre optic proximity instrument which can be used, inter alia, in bearing analysis and monitoring applications is also disclosed in U.S. Patent 4,247,764. Such probes can be used to detect degradation of bearings by wear debris analysis and vibration analysis.

According to the present invention there is provided a method of monitoring the total load in a rotating bearing comprising the steps of detecting the variations in stress or strain characteristic at a given point, measuring the amplitude of said variations and translating said amplitude into a total load representation.

The invention will be more particularly described with reference to the accompanying drawings, in which:—

Fig. 1 illustrates the distribution of forces resulting from axial thrust in a rotating ball bearing,

Fig. 2 illustrates various sites for stress/strain sensors in a rotating ball bearing,

Fig. 3 illustrates the variation in stress/strain at areas around a rotating ball bearing,

Fig. 4 illustrates the typical relationship between amplitude of variation of stress or strain and total bearing load, and

Fig. 5 illustrates a typical circuit arrangement for processing strain gauge signals.

In a typical ball bearing axial thrust F_a on a shaft 10 is transmitted via the bearing inner race 11 and balls 12 to the outer race 13. Because of the geometry of the balls and outer race the resultant force F_r is transmitted via the outer race to the bearing housing 14 and retainer 15 from the point of contact between the ball and the outer race. This resultant force is made up of component forces f_a (axial) and f_b (radial). It is clear, therefore, that there are various sites where a sensor may be positioned to detect the stress or strain variations at the ball pass frequency. These are indicated in Fig. 2. The sensor must be of a size of the order of or preferably smaller than the distance between two successive balls. The sensor may be a strain gauge of a resistive, piezoresistive, piezoelectric, inductive, capacitive or fibre optic type. Modern technology has produced semiconductor based strain gauges that are extremely compact and yet highly sensitive. Such sensors can be positioned in a depression 21, 22, 23 either in the radial or axial faces of the bearing outer race 13, in a depression 24, 25 on the inner face of the housing 14, or in a depression 26 on the inner face of the retainer 15. These sites all monitor one of the force components f_a, f_r. Another place 27 where a sensor can be placed to monitor an axial component of force is between the bearing race and the housing.

The variation in stress or strain as successive balls pass a given point is very approximately sinusoidal, as shown in Fig. 3. This is drawn schematically to show how the maximum and minimum stress or strain vary as the balls 12 move against the outer race 13 at approximately half the speed of the inner race 11. The stress or strain is at a maximum at a ball position and at a minimum midway between successive balls. The sensor will detect this (approximate) sinusoidal variation at the ball pass frequency. The amplitude of the variation is dependent on the total load F_a. In many cases the ball pass frequency is known, and remains nominally constant with load variations, otherwise the ball pass frequency may be obtained by the use of another detector for shaft rpm or actual ball speed. Thus very sensitive signal detection methods may be employed to detect the stress or strain variation to enhance the signal-to-noise ratio.

As the total load on the bearing changes the variation in the stress or strain characteristic detected at the ball pass frequency will be as depicted in Fig. 4. There thus exists a relationship between the amplitude of stress or strain variation at the ball pass frequency and the total load experienced by the bearing. The load on the bearing may therefore be inferred by using a sensor which is sensitive to variations only.

There are several advantages to this method. Being sensitive to variations only the sensor is not affected by being clamped to the area around the bearing, nor if such a force is changed by temperature or other effects (as long as the sensor is linear). It also would not be sensitive to pressure gradients or hydrostatic pressure. Furthermore, dc drift of the sensor would not matter, and in any event, alternating signals are easier to process electronically than dc signals.

Fig. 5 illustrates a circuit for processing signals received from a pair of strain gauge sensors located on either side of a bearing outer race, the sensors 31, 32 being operated as two arms of a Wheatstone bridge. The other arms of the bridge are formed by resistors 33, 34. Variable resistance 35 is used to balance the bridge for calibration. The bridge is fed with a d.c. voltage V. The bridge output is fed to an amplifier 36. The amplified output from the bridge can be presented on an oscilloscope 37 or fed to a signal analyser 38. If a "carrier" system is used the supply voltage V can be replaced by a carrier frequency, e.g. at 5KHz, and the amplifier would be a carrier amplifier followed by a demodulator.

Several sensor types have already been tested and shown to perform satisfactorily down to −200°C. These have included piezoelectric

ceramic washers, differential piezoelectric ceramics (two ceramic 'back to back' spaced by an insulating layer), resistive strain gauges, and fibre optic displacement/strain sensors. The fibre optic sensor consisted of a reflected amplitude modulation measurement using a single fibre and a diaphragm force transmission/seal. Fibre optics provide an intrinsically safe sensory system. The sensors are calibrated in situ by applying a known load to the bearing, usually by applying loads directly to the shaft.

CLAIMS

1. A method of monitoring the total load in a rotating bearing comprising the steps of detecting the variations in stress or strain characteristic at a given point, measuring the amplitude of said variations and translating said amplitude into a total load representation.

2. A method according to claim 1, wherein one or more stress or strain sensors are placed adjacent the outer race of a ball or roller bearing to detect variations in the stress or strain characteristic.

3. A method according to claim 2, wherein two sensors are placed to detect coincident maxima and minima respectively, said two sensors being electrically connected as two arms of a Wheatstone bridge circuit.

4. A method according to claim 2 or 3, wherein the sensors are piezoelectric strain gauge.

5. A method according to claim 2 or 3, wherein the sensors are fibre optic displacement sensors.

6. A method of monitoring the total load in a rotating bearing substantially as described with reference to the accompanying drawings.

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